NOAA Testbed USWRP Workshop

The Weather Research and Forecasting (WRF) Developmental Testbed Center (DTC)

Steve Koch

Director, Global Systems Division (GSD)
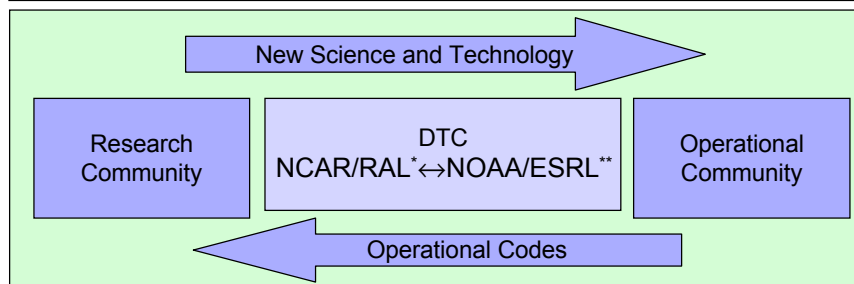NOAA Earth System Research Laboratory (ESRL)

Deputy Director, DTC

DTC THE DEVELOPMENTAL TESTBED CENTER (DTC)

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Fundamental Purpose of WRF DTC

To serve as a bridge **between research and operations to** facilitate **the activities of the Numerical Weather Prediction (NWP) Community**

- **Research**: functionally equivalent operational environment to test and evaluate new NWP methods over extended retrospective periods

- **Operational**: benefits from DTC Testing and Evaluation of strengths and weaknesses of new NWP advances prior to consideration for operational implementation

New Science and Technology →

| Research Community | DTC NCAR/RAL*↔NOAA/ESRL** | Operational Community |

← Operational Codes

*National Center for Atmospheric Research / Research Applications Laboratory
**National Oceanic and Atmospheric Administration / Earth System Research Laboratory

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Management Structure in Transition

- Management by DTC Director (Bill Kuo / NCAR) and Deputy Director (Steve Koch / NOAA)
- Priorities set by funding agencies with guidance from Advisory Board

	Executive Committee	Members from funding agencies	Appoints DTC director, executive oversight
Once charter is approved	**Management Board**	Director, deputy directors, members from funding organizations	Annual operating plan and budget
	Advisory Board	Members from operational and research communities	Strategic direction and objectives

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National WRF DTC Funding

Funding Sources: NOAA, NCAR, AFWA, FAA, NSF

FY07 — AFWA+

FY09 — NOAA+ HFIP?

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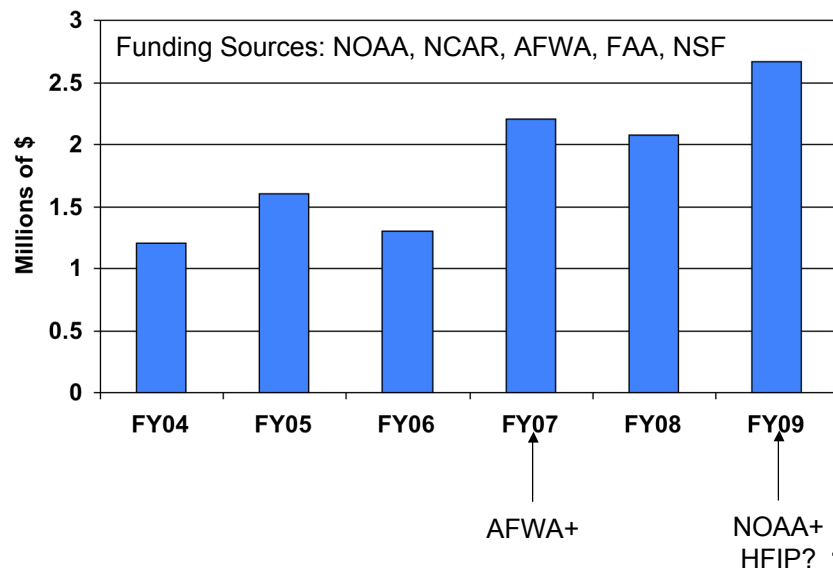
WRF DTC Activities - I

Support codes to the community

- User support for the WRF Model in the context of a unified WRF system (DTC is member of WRF Developers Committee)
    - Share with NCAR / MMM support of ARW, as well as pre- (WPS) and post-processor (WPP)
    - Share with NOAA NCEP support of WRF Non-hydrostatic Mesoscale Model (NMM) dynamic core
- MET for forecast verification
    - State-of-the-art model verification software
    - Traditional grid-to-grid and grid-to-point verification
    - Advanced verification based on spatial techniques
- Developing
    - GSI (NCEP 3DVAR Analysis)
    - HWRF (NCEP Hurricane WRF model)

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WRF DTC Activities - II

Visitor Program

- Fund scientists in projects that lead to increased capabilities of WRF models (physics and dynamics), model testing and evaluation, data assimilation, ensembles, and verification techniques
- Offer one month of salary plus travel and per diem
- Scientist can work at DTC (NCAR or NOAA ESRL) or an operational center

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WRF DTC Activities – III

- **Verification System for internal use (T & E activities)**
  - □ Expertise with NCEP Verification Packages
  - □ Routines developed to create and query databases and generate plots
- **Development and support of verification tools to the community**
  - □ Model Evaluation Tools (MET)
- **Scientific body for testing, development and advancing of verification techniques**
  - □ Routine use of uncertainty measures (confidence intervals and others) to communicate verification results
  - □ Visitor program
  - □ Inclusion of "advanced" verification techniques in MET

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WRF DTC Activities – IV

Computational Infrastructure for Testing and Evaluation

Package	Function
SI/WPS	Pre-processing
WRF	Forecast model
WPP	Post-processing
NCL	Plotting
NCEP Vx	Verification
NHC Vx	Hurricane Vx
GFDL Tracker	Vortex Tracker
Database	Store Vx results
Website	Display
Archival	Data storage
Scripts/Workflow	Automation

- Porting
- Automation
- Interoperability

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Computational Challenges

- Porting individual codes/scripts to multiple platforms
  - ☐ Lots of code from multiple institutions (NCAR, NCEP, NHC etc.)
  - ☐ Some code must be adapted to new requirements
  - ☐ Code and scripts must run on multiple systems (e.g. bluefire, wjet)
- Automation
  - ☐ Need to do hundreds of end-to-end runs
  - ☐ A single end-to-end run may consist of hundreds of tasks
  - ☐ Tasks have dependencies (on other tasks, on data, on time of day)
  - ☐ Must be fault tolerant
- Data movement and analysis
  - ☐ Assemble input data from multiple institutions
  - ☐ Transfer and Archive results
  - ☐ Deliver results for display and analysis
    - Web page graphics displays
    - AWIPS, FX-Net
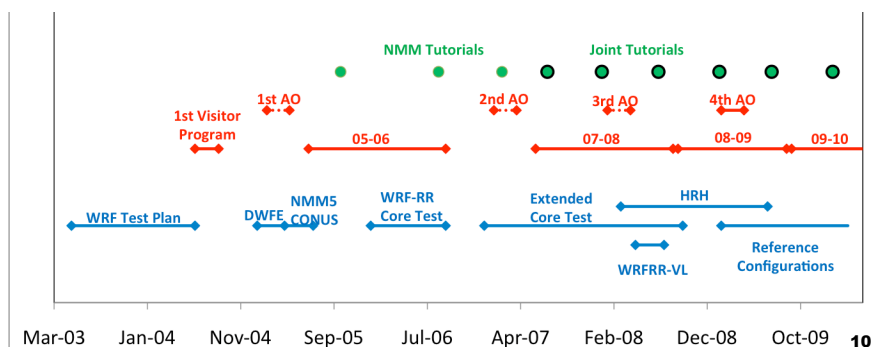   - AB Verification database and web display

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WRF DTC Activities - V
Testing and Evaluation activities (slides to follow)

Operational Community

- Provide guidance for next generation Operational Configurations

Research Community

- Provide baselines for evaluating impacts of new techniques
- Aid in selecting configurations for research projects

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WRF Test Plan
Impacts on NCEP

- Demonstrated the 6 WRF members tested were qualified to run as an ensemble system

- 21 Sept 2004: IOC - 2 members (ARW & NMM – no physics swapping)

- 6 Dec 2005: 6 WRF members added to NCEP Short-Range Ensemble Forecast (SREF)

- New WRF-based SREF outperformed the current one in all ensemble aspects

DTC Winter Forecast Experiment

Goal: Provide real-time experimental model guidance for winter weather over a large domain using 2 WRF configurations w/ explicit convection

Objectives
- Expose forecasters to WRF at very high resolution prior to the first scheduled operational implementation at NCEP

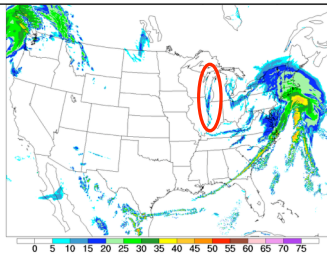- Determine whether encouraging results from warm season 4-km WRF runs carry over to winter

DTC Winter Forecast Experiment

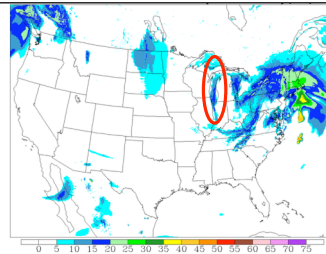**Composite Reflectivity at 03 UTC 23 January 2005**

Lake-effect snowbands

Observed

050123/0300 WSI NOWRAD 2 KM US MOSAIC
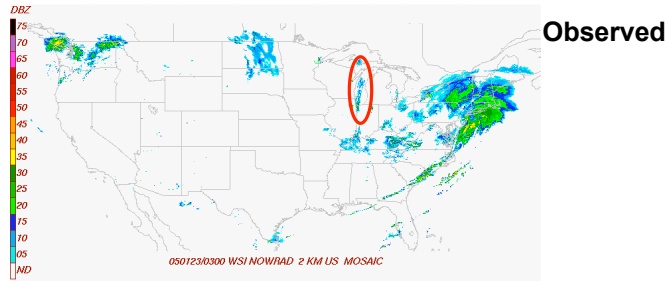
WRF-ARW

WRF-NMM

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DTC Winter Forecast Experiment
Impact on NWS

- Provided valuable hands-on experience to forecasters with high-resolution (5-km) WRF model output over CONUS

- NCEP added simulated reflectivity to diagnostic fields and made available to WFOs

- 28 June 2005: Results using high-resolution WRF with explicit microphysics alone prompted NCEP to upgrade resolution of HRW (NMM 8.0 to 5.1 km / ARW 10 to 5.8 km)

- DTC demonstrated importance of using statistical tests of significance when comparing forecast skill from multiple models
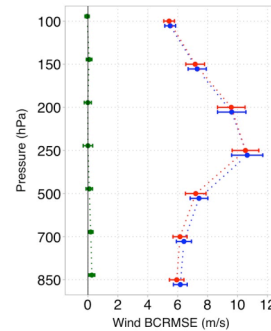
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WRF Core Test: Rapid Refresh (RR)
Impact on NWS

Goals

- Conduct controlled experiments carefully comparing the 2 WRF dynamic cores.
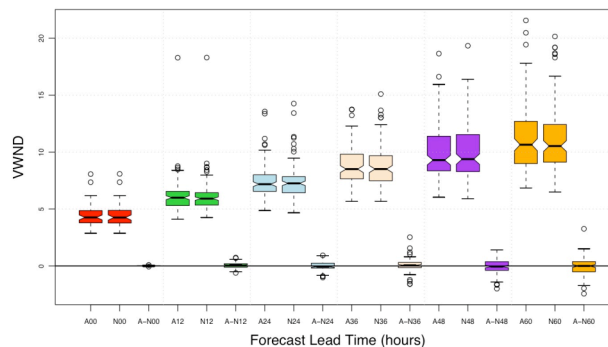- Provide datasets to support GSD's dynamic core recommendation to NCEP for WRF-RR

Impacts

- 1st ever "clean" WRF dynamic core comparison conducted anywhere
- ARW selected for initial implementation of WRF-RR at NCEP scheduled for 2010

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Extended Core Test

CT2007 ARW and NMM BCRMSE: AnnualTime Period, P250, VWND

- ARW and NMM results are not substantially different
- Inter-core differences do not grow in time
- Potential for transferring research done with one core to the other

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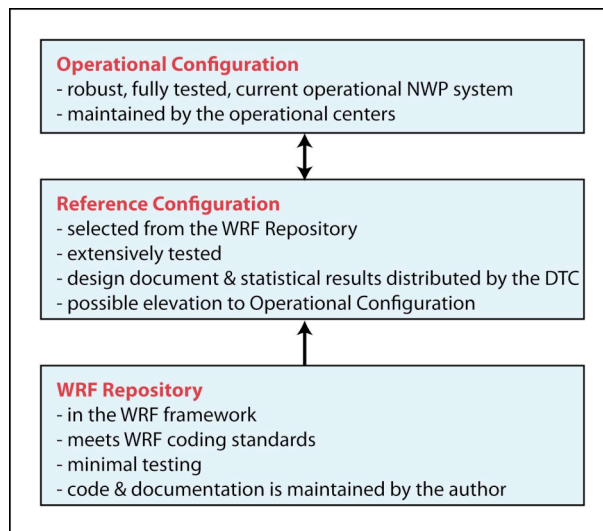
Statistical Significance Assessment
Confidence Interval (CI) Methodology

- Single model configuration
  - Surface and upper air
    - Auto-correlation correction
    - Normal distribution
  - QPF
    - Bootstrap
- Comparison of 2 model configurations
  - Pairwise technique

  New Tools: MySQL database + R-language scripts to gather data, compute aggregate statistics, pairwise differences, and CIs
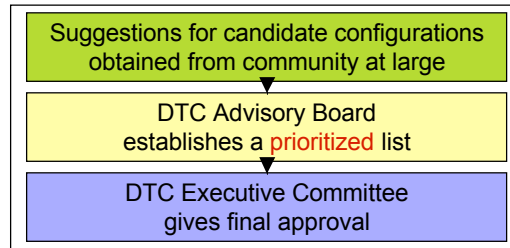
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WRF Reference Configurations

Operational Configuration
- robust, fully tested, current operational NWP system
- maintained by the operational centers

Reference Configuration
- selected from the WRF Repository
- extensively tested
- design document & statistical results distributed by the DTC
- possible elevation to Operational Configuration

WRF Repository
- in the WRF framework
- meets WRF coding standards
- minimal testing
- code & documentation is maintained by the author

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RC Selection Process
(if approved under DTC Charter)

Suggestions for candidate configurations
obtained from community at large

DTC Advisory Board
establishes a prioritized list

DTC Executive Committee
gives final approval

– **Balance between traceable history (maintaining previous RCs) and new capabilities (testing new RCs)**

*DTC Advisory Board
Government agencies
Private sector
Academic community

DTC Executive Committee
AFWA NCAR NWS OAR

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WRF DTC User Support

- Software Management, User's Websites, Email lists, Tutorials are all provided to the community
- Currently provided for:
  - □ WRF (model, pre- and post-processors)
    - In collaboration with MMM
  - □ Model Evaluation Tools (MET)
- Near-term:
  - □ GSI Data Assimilation (DA) System
  - □ HWRF (coupled atmospheric, ocean, wave system)
- Long-term:
  - □ Ensemble

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GSI Support

- **Gridpoint Statistical Interpolation (GSI):**
  - Variational data analysis system developed by NCEP
  - Implemented in several operation systems such as GFS and NAM
  - Used in Rapid Refresh
  - AFWA is planning to use it in operation

- **DTC goals**
  - Test and evaluate GSI
  - Support research community to use GSI
  - Feed research community contributions back to NCEP

User Support: GSI User's Guide

- Draft completed
- Proofread by GSD & NCEP
- Revised based on feedback
- Update to match GSI version to be released
- Final review

(RED = work in progress)

User's Support: Community GSI User's Page
http://www.dtcenter.org/com-GSI/users/

- Completed overall structure of web site

- Populated with available materials
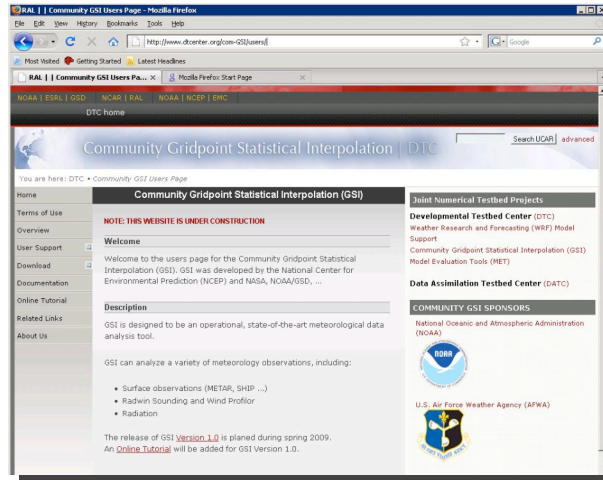
Hurricane WRF (HWRF) in the DTC
Shaowu Bao

Shaowu Bao

Jian-Wen Bao, Ligia Bernardet

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Model Evaluation Tools (MET): Community Tools for Forecast Evaluation

Tressa Fowler

Barbara Brown, John Halley Gotway, Randy Bullock, Eric Gilleland, David Ahijevych, and Tara Jensen

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Future Activities

- Continue activities presented in this review
- Ensemble Forecasting
  - □ Priority for NCEP
  - □ DTC needs to develop expertise
  - □ Possible new hire(s)
- Hurricane Forecast Improvement Project
  - □ Port HYCOM ocean model to couple with NMM

- Possibly extend beyond WRF
  - □ Earth System Modeling Framework (ESMF)
  - □ Other operational models

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Benefits of DTC to NOAA

- **Increased cost savings**
  - Reduce time required at NCEP to bring Contributed Code to state of readiness for operational implementation
  - DTC distributed resources will reduce burden on NOAA to provide all the necessary resources to accomplish its technology transition goals
- **Improvements to productivity**
  - Faster code implementation means faster rate of improved weather services to the public
  - DTC will permit the operational forecasting centers to fully utilize the scientific resources in the research community (including OAR labs)

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Possible Interactions of DTC with HMT

- New verification capabilities for RFC event-based verification and spatial verification methods for ensemble-based precipitation forecasts.

- Determine impact of ground-based GPS water vapor observations and space-based radio occultation data on QPF associated with significant precipitation events.

- Investigate impacts of model physics on performance of WRF in the prediction of hydrometeorological variables in the HMT focus regions

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Possible Interactions of DTC with HWT

- Application of spatial verification techniques (MODE) to convective-resolving models run during Spring Exp.

- Development and application of methods for verifying high-resolution model ensembles

- Investigate impacts of model physics on performance of WRF in the prediction of severe storm environment

- DTC Visitor Program (Univ. of Oklahoma, REU)

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Possible Interactions of DTC with SPoRT - GOES Proving Ground - JCSDA

- Collaborate to transition satellite observations/products and research capabilities to the operational weather community by demonstrating the ability of these data to systematically improve short-term forecasts on a regional scale.

- DTC could use its experience during DWFE to help establish a two-way dialog between forecasters who will use WRF with the GOES-R products and those who are developing new products and application.

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Possible Interactions of DTC with SPoRT - GOES Proving Ground - JCSDA

- Good opportunity: Impact of assimilating satellite data on short-range forecasting using GSI with enhanced capabilities (e.g., WRF-Rapid Refresh hourly updating with multi-sensor cloud analysis):

  - ☐ Evaluation of proxy ABI radiances and hyperspectral sounder data generated from model-simulated data in enhanced versions of GSI would require development of new methods for verification using forward models.

  - ☐ DTC could evaluate impact of synthetic GOES-R imagery for improving the two-moment prediction of hydrometeors in WRF.

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Possible Interactions of DTC with JHT

- DTC provides community support for HWRF code management. JHT could support visiting scientists at the DTC to experiment with HWRF research models.

- JHT has a stated objective to "complete tests in a quasi-operational environment of new tools, techniques, etc. provided by funded researchers". Such an environment is uniquely provided by the DTC to researchers.

- HWRF being developed by DTC in the repository will include coupling to HYCOM, WAVEWATCH, LSM, storm surge and hydrology models for inland flooding. Much opportunity here for jointly funded projects.

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Possible Interactions of DTC with SIP

■ SIP is "a focal point for developing and supporting a closer relationship between weather researchers, operational forecasters, relevant end users, and social scientists concerned with the impacts of weather and weather information on society".

■ DTC can provide expertise in the areas of modeling, data assimilation, and verification as needed to realize the goals of SIP. Potential topics might include:
  □ Communicating weather forecast uncertainty
  □ Quantifying the impact of NWP information on economic sectors
  □ Determining societal value of improved QPF information

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Possible Interactions of DTC with CSTAR

■ Key CSTAR objective is to bring current NWS-supported collaborative activities with the academic community into a structured program and to create a cost-effective transition from basic and applied research to operations and services.

■ Strong linkage with DTC Visitor Program could be fostered, possibly through COMET Outreach Program.

■ Experimental versions of WRF being run by universities in support of local/regional NWS offices could be subjected to more rigorous and systematic evaluation.

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Possible Interactions of DTC with THORPEX

- An international program to improve the skill of high-impact weather forecasts for the benefit of society, economy, environment. A chief goal: accelerate improvements in the accuracy of NWP, probabilistic forecasting and the description of IC uncertainty.

- May make the most sense once DTC mission has been expanded to include testing and evaluation of global models for accelerating improvements in the accuracy of 1-day to 2-week high-impact weather forecasts.